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ABSTRACT

To identify when visual information is acquired during reading, an experiment was designed in which rapid display changes were made contingent upon the state of the eye. This was accomplished by programing a computer to detect within a few milliseconds whether the eye is in a saccade or fixation. By then replacing a line of text with some other line for a 30 millisecond period during the saccade or at different times during the fixation it was hoped that it could be determined when the reader was sensitive to visual input from the text. The subjects were college undergraduates. The results showed that (1) little, if any, visual information is acquired during the saccade; (2) saccadic threshold elevation does not substantially reduce the acquisition of visual information during the early portion of the fixation; (3) visual information is being acquired throughout the fixation; (4) the kind of visual information being acquired may change over the course of the fixation; and (5) eye movements are under rather immediate control, responding to stimulus manipulations within the fixation where the manipulation occurs. (MKN)

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## THE ACQUISITION OF VISUAL INFORMATION DURING FIXATIONS AND SACCADDES IN READING\*

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Vision research has demonstrated that the threshold for detecting visual information is raised during saccadic movements, and during a short period just prior to and following the saccade. This has been referred to as saccadic suppression. This elevation of visual threshold has been reported (Volkman, et. al., 1968) to occur some 20 msec. prior to the saccade, reach a maximum during the saccade, and continue for some 75 msec. after saccade onset. This raises the question of whether or not visual information is "taken in" during this period of saccadic suppression.

However, this is actually part of the more general question: When, during reading, is visual information acquired? This general question can be divided into two specific questions:

- 1.) Is visual information acquired during the saccade? and
- 2.) When is visual information acquired during the fixation?

Answers to these questions will have implications for the effect of saccadic threshold elevation, models of the reading process and models of eye movement control.

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Some models of the reading process (e.g., Smith, 1971) argue that visual information is only used for a short portion of the fixation, for about 50 msec. at the beginning of the fixation. Others (e.g., Gough, 1972) argue that visual information is used throughout the fixation. Haber and Hershenson (1973) say, (p. 109) "...for the 100 milliseconds before, during, and after the movement, the chances of noticing new information or fine detail is sharply reduced." This would seem to imply that new information is acquired during the middle portion of the fixation.

In order to answer these questions an experiment was designed in which rapid display changes were made contingent upon the state of the eye. This was accomplished by programming the computer to detect within a few msec. whether the eye is in a saccade or fixation. The parameters supplied to the computer with each individual experimental line then permitted the experimental manipulations (display changes) to be performed in the proper time sequence. By replacing the line of text with some other line for a 30 msec. period during the saccade or at different times during the fixation it was hoped that it could be determined when the reader was sensitive to visual input from the text. Furthermore, by systematically varying the kinds of changes that were made it could be determined if different kinds of

visual information are used at different times.

Subjects were college undergraduates who had average or above average scores on the Davis reading test and who had normal, uncorrected vision. Subjects read five passages of thirty lines each. On the first two and last three lines of each passage no experimental manipulations occurred. On the remaining 125 lines the experimental conditions were randomized and counterbalanced.

The substitution of one line by another occurred at one of five different times. These are called the "timing conditions":

- (1) S0 Text substitution occurs at the start of the saccade and continues for 30 msec. or the end of the saccade whichever occurs first
- (2) F0 Text substitution occurs at the start of the fixation and continues for 30 msec. or the end of the saccade whichever occurs first
- (3) F30 Text substitution occurs 30 msec. after the start of the fixation and continues for 30 msec. or the end of the fixation whichever occurs first
- (4) F100 Text substitution occurs 100 msec. after the start of the fixation and continues for 30 msec. or the end of the fixation whichever occurs first
- (5) F200 Text substitution occurs 200 msec. after the start of the fixation and continues for 30 msec. or the end of the fixation whichever occurs first

If the saccade or fixation continued after the expiration of the 30 msec. presentation time for the text substitution then the original line was displayed for the remainder of the saccade or fixation. In other words, the text

substitution was presented for a maximum of 30 msec. and was immediately replaced by the original line of text. For example, if a saccade was less than 30 msec. in duration and the substitution was to be presented during the saccade then the substitution could only be presented until the end of the saccade. In the case of a fixation whose duration was 225 msec. and the substitution was to occur 100 msec. after the start of the fixation the text substitute would be displayed only until the start of the following saccade, i.e., for 25 msec.

Figure 1 illustrates the five timing conditions. The original text line was displayed until Point A at which time one of the five substitute lines was displayed for 30 msec. (conditions permitting). At Point B the original text line was again displayed until the next trial.

There were five types of text lines that could replace the original text during the 30 msec. substitution period. These will be called the "text substitution" conditions:

- (1) Control      Text changes to an identical line
- (2) Blanks      Text changes to a blank line
- (3) X's          Text changes to a line of upper case X's
- (4) Confusable   Text changes to a line in which each character is replaced by its most confusable alternative as experimentally determined for the display used
- (5) Dissimilar   Text changes to a line from another passage with few visual or linguistic similarities

The five different text substitutions are illustrated for a typical line in Figure 6.

There were 25 combinations of text substitution and timing conditions. One of each of these combinations was assigned to each experimental line of a passage for a given subject. Two changes were scheduled to occur during the reading of each line: on the third and sixth forward saccade or the fixations immediately following depending on the particular timing condition. These saccades will be called "initiating saccades", since the display changes occurred during them or at some specified time following their completion. Figure 2 illustrates a typical record for an experimental line. Text substitutions during the saccade occurred in Saccade One (SAC 1) while substitutions during the fixation occurred in the fixation following Saccade One, Fixation One (FIX 1). Saccade Two (SAC 2) and Fixation Two (FIX 2) follow immediately.

The experiment was conducted using a Digital Equipment Corporation (DEC) DECLAB 11/40 laboratory computer system to control the display and data collection (see McConkie, Zola, Wolverton & Burns, 1978 for details).

The data collected included the length, in character positions, of the initiating saccade (SAC 1), the duration, in msec., of the following fixation (FIX 1), the length, in

character positions, of the next saccade (SAC 2), and the duration, in msec., of the fixation following it (FIX 2).

An analysis of variance (BMD08V) was performed on these data. This analysis yielded significant effects for Timing Condition, for Text Substitution Condition, and for the interaction between these factors for the duration of Fixation 1 and of Fixation 2. The Timing Condition was found to affect the length of Saccade 2.

The question of what visual information is acquired during the saccade can now be approached. A Newman-Keuls test of differences among means (Kirk, 1968) indicates that the presence of inappropriate text during the saccade (S0 in Figures 3, 4, & 5) has no significant effect upon the duration of FIX 1 or FIX 2 or the length of SAC 2. It may be concluded that visual information acquired during the saccade is not important for reading.

What about the effect of saccadic threshold elevation (saccadic suppression) on reading? The presence of inappropriate text during the first 30 msec. or the second 30 msec. of the fixation (F0 and F30, resp., in Figure 3) significantly increases the duration of that fixation. Moreover, this increase is of the same order of magnitude as that which occurs later in the fixation (F100 and F200 in Figure 3). It is concluded, therefore, that saccadic

threshold elevation has little effect upon reading, at least during the early portion of the fixation.

What about the effect of saccadic threshold elevation at the end of the fixation? There were a few chance occurrences of the presentation of inappropriate text during the last portion of the fixation, but too few to justify statistical analysis. This question must await future research.

When is visual information being acquired during the fixation? The presentation of inappropriate text at any time during the fixation results in a significant increase in the fixation duration of that fixation. In addition, presentations 200 msec. after the start of the fixation (F200) resulted in significant increases in the following fixation (FIX 2, see F200, Figure 5). It seems clear, then, that visual information is being used all the time during the fixation.

What kind of visual information is acquired at different times during the fixation? Referring to the trends of the various text substitutions shown in Figure 3, it seems evident that the type of information present changes the effect on fixation duration over the course of the fixation. Confusable text, for example, contains all the word shape information of the original text, yet it results in a significant increase in fixation duration when presented 30

msecs. after the start of the fixation (F30 in Figure 3). This implies that the specific information required for letter and/or word identification is required at this point. This condition appears to have less effect at other times. Further analysis of these data and future research will be directed at discovering more precisely when various kinds of visual information are used during the fixation.

In summary, this study shows that during reading:

- (1) Little, if any, visual information is acquired during the saccade;
- (2) Saccadic threshold elevation (saccadic suppression) does not substantially reduce the acquisition of visual information during the early portion of the fixation;
- (3) Visual information is being acquired throughout the fixation;
- (4) The kind of visual information being acquired may change over the course of the fixation;
- (5) Eye movements are under rather immediate control, responding to stimulus manipulations within the fixation where the manipulation occurs.

Footnote

- \* This paper was presented at the 1979 meeting of the American Educational Research Association in San Francisco, Ca. The research discussed in this paper was supported by Grants MH24241 and MH32884 from the National Institute for Mental Health.

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FIGURE 1

Illustration of the five timing conditions. Original line of text is displayed until point A. At point A a substitute line is displayed for 30 msecs, point B. At point B the original line is displayed again until the next scheduled substitution

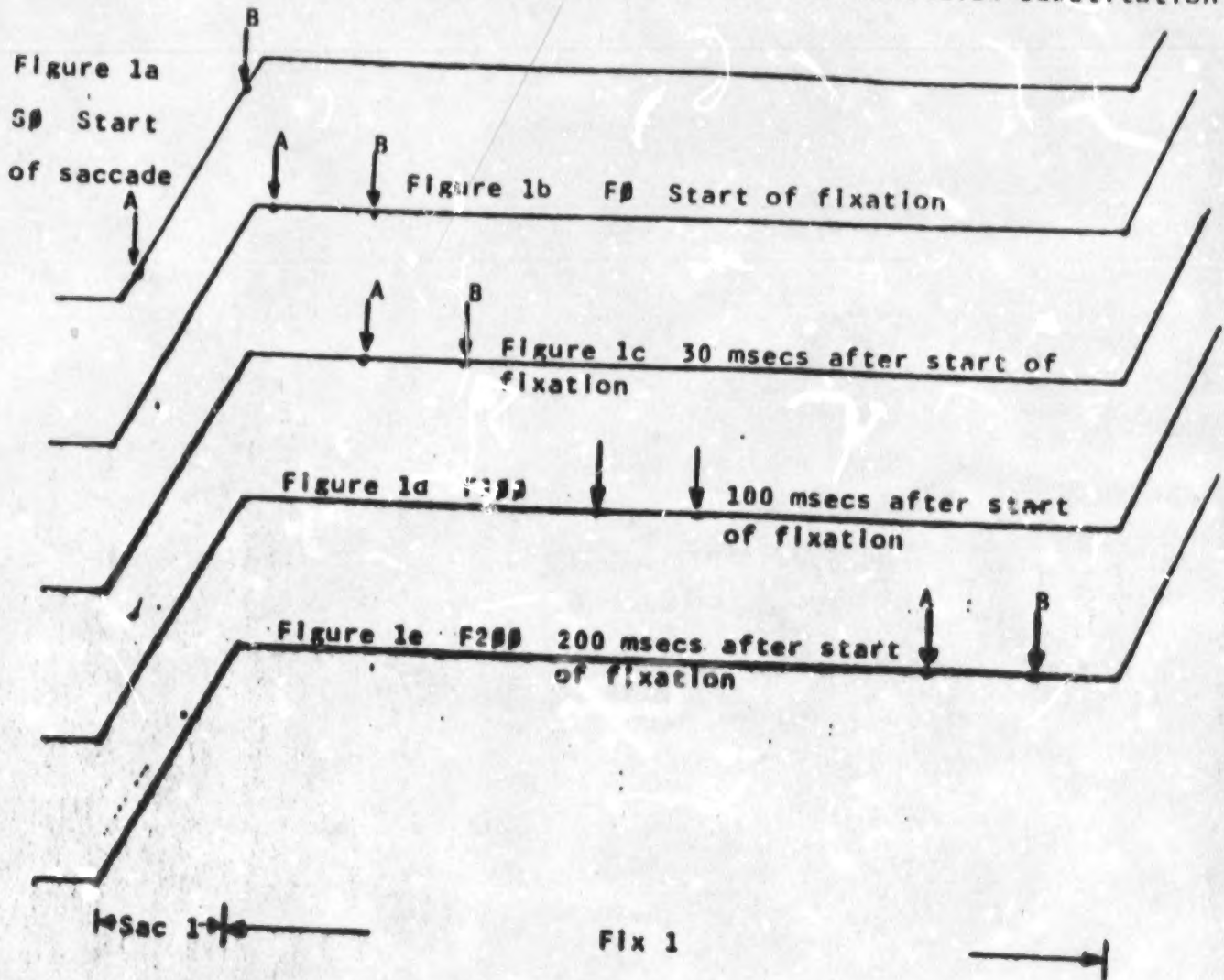


FIGURE 2

Schematic representation of data taken from a typical line of reading showing the sequence of events for a given experimental line.

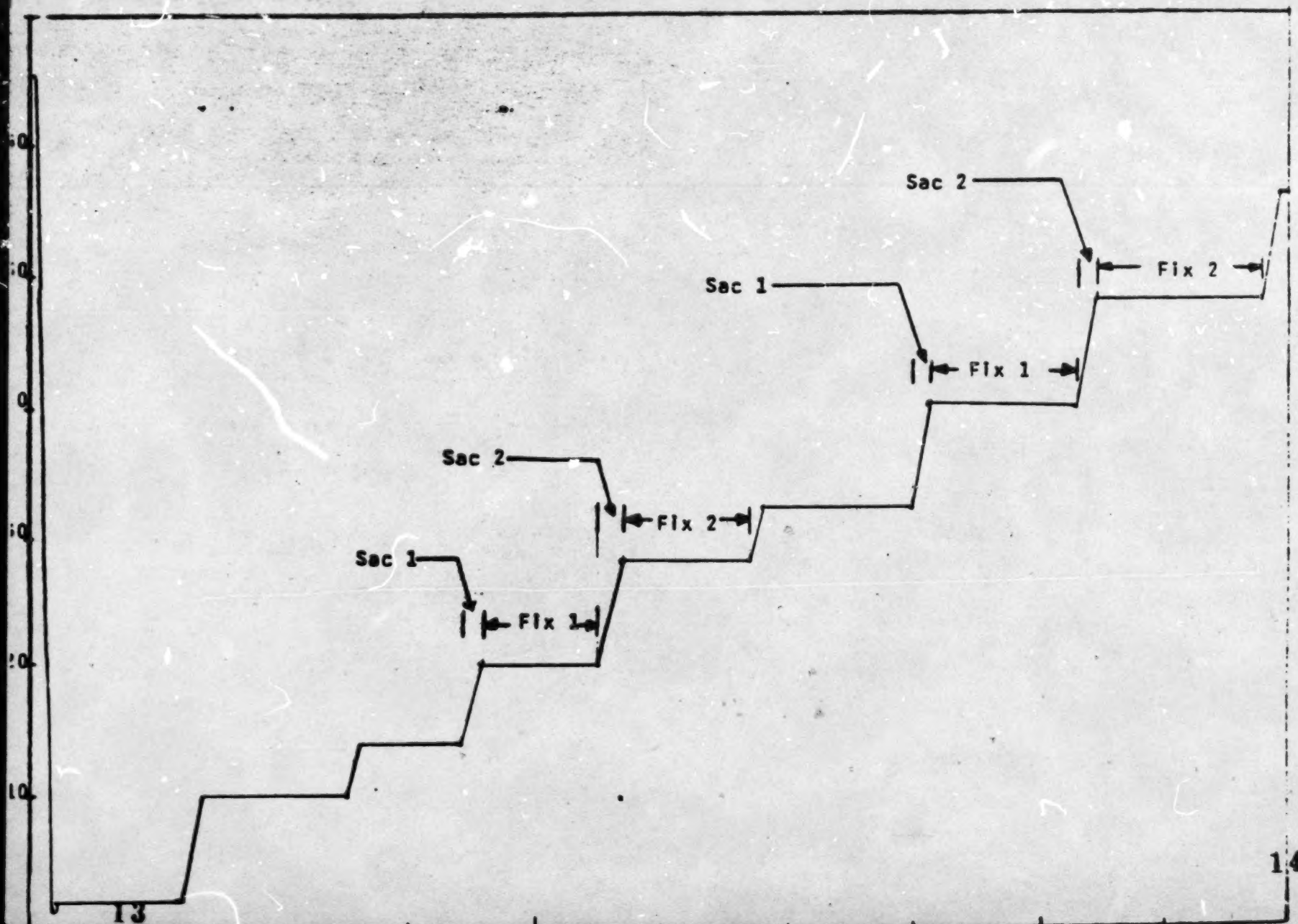


FIGURE 3

PLOT OF DURATION OF FIXATION 1 TEXT CONDITION VS  
TIMING CONDITION

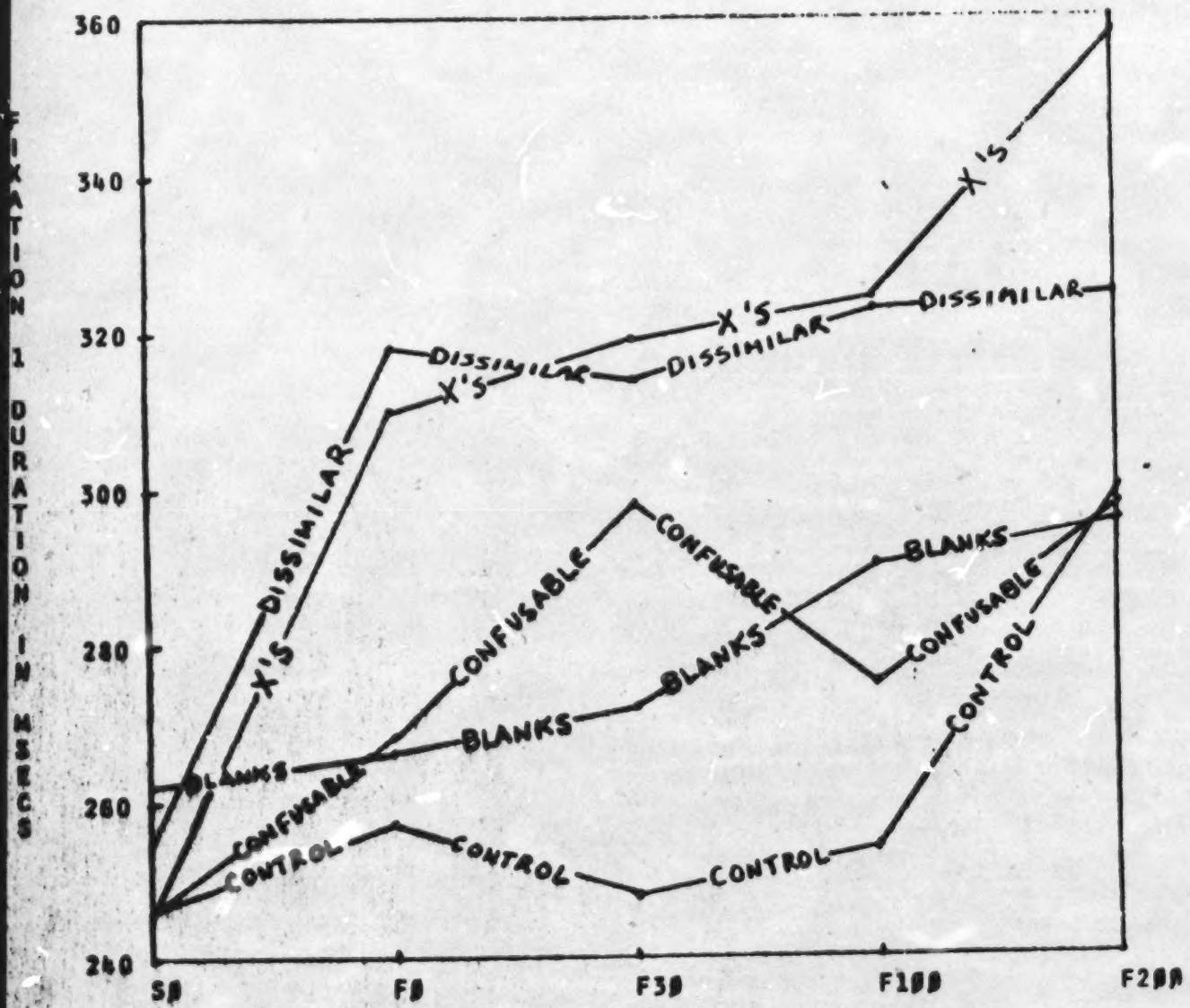


FIGURE 4

PLOT OF LENGTH OF SACCAD 2 VS TIMING CONDITION

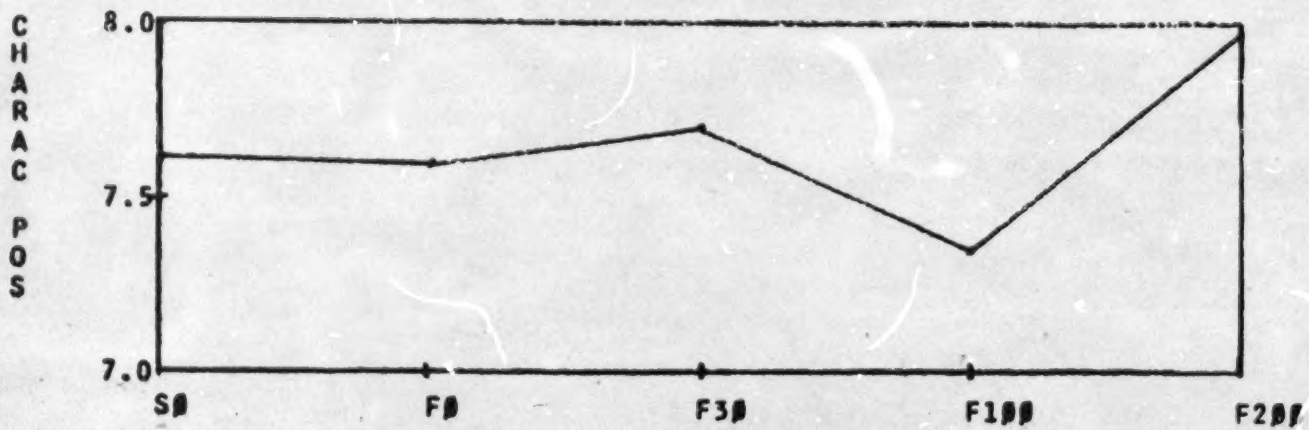


FIGURE 6

FIVE DIFFERENT TEXT SUBSTITUTIONS FOR A TYPICAL LINE

Orig: In Orion. All but the nearest stars are observed behind a  
 Cont: In Orion. All but the nearest stars are observed behind a  
 Bks: XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX  
 X's: 1m Cf1cm. Hll dvr rka maefaar arefa efa cdaafuab dakimb e  
 Diss: leaves seemed to unfold as she watched. Enle thrust a pan

FIGURE 5

PLOT OF DURATION OF FIXATION 2 TEXT CONDITION VS TIMING COND

